SECTION 5

SOILS INVESTIGATION

General

A soils investigation shall be required if the developer elects to utilize a pavement section based on good soils in a single family residential subdivision. A soils investigation will not be required if the developer elects to utilize a pavement section based on poor soils.

In the event the streets are layed out in an area that may require the removal of unsuitable material, the Department reserves the right to request a soils investigation to determine the extent of the unsuitable material to be removed.

Streets within an industrial park will require a soils investigation to determine the required pavement section.

Guidelines for Soils Investigation

The specifications and guidelines for a soils investigation are found as an Appendix to this Section.

Soil Survey for Subdivision

A soil survey shall be made for all proposed streets within the subdivision. To insure uniformity of data the following guidelines and methods are provided for those performing the field work:

Equipment - Any equipment can be used that will enable soil to be removed by stratum to the desired depth. Normally a 4 inch (102 mm) hand auger is sufficient.

Locations - Sampling locations, normally called borings, shall be spaced no more than 300 feet (91 m) apart along the centerline of the proposed streets. Offsets from centerline shall be within the area of proposed roadway. Borings should be located in such a manner that all questionable areas (i.e. depressions and old stream beds) are investigated.

Depth - Borings shall be made to a depth adequate to sample soils 3 feet (.91 m) below the subgrade of the proposed pavement system.

Sampling -Soil shall be sampled by stratum. Normally, when using a hand auger the soil in the auger is compared with the previous auger load. As soon as a change in the soil composition is noted, a new sample is started and the depth to the nearest half foot is recorded. A minimum sampling rate of one sample per foot of boring is required regardless of soil condition encountered. Sample size should be sufficient for the required laboratory testing.

Water Level -When water is encountered, borings should be left open until water level stabilizes and then depth to water should be recorded.

Data -A log of each boring should be kept, recording the following information:

a) Name of street,
b) Location of boring - station and offset,
c) Surface elevation referenced to roadway grade,
d) Date of boring,
e) Depth of each stratum,
f) Sample number,
g) Soil description (this is not required; however, the presence of unusual soil conditions must be noted on the log), and
h) Depth to water if encountered.

These guidelines are provided to instruct personnel involved with soil investigation work for subdivisions. It is the intent to standardize methods used by the developer for obtaining and presenting soils data.

The guidelines for the soil survey detail minimum standards acceptable for the field work. These are similar to the standards used by the Department when investigating soils for roadway design.

Test methods for soils specified herein are taken from procedures found in the Delaware Department of Transportation Materials Manual. These procedures are based on tests detailed in American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Transportation Materials and Methods of Sampling and Testing as described below:

Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Tests - This procedure follows AASHTO T87 and contains only minor changes. Irrelevant sections were deleted.

Particle Size Analysis of Soils

This procedure is based on AASHTO T88 with the major change being the deletion of the hydrometer test.

Determining the Liquid Limit of Soils

The procedures in this test are based on AASHTO T89 with the major change being the deletion of the referee test.

Determining the Plastic Limit and Plasticity Index of Soils

This procedure follows AASHTO T90 and contains only minor changes.

Laboratories performing the testing for soil investigations of subdivisions must either follow these modified procedures or corresponding procedures specified in the AASHTO Standard Specifications or ASTM Standards. Methods which deviate from any of these procedures must be submitted to the Department for approval.

Results of soil investigations submitted to the Department should contain:

a) a plan view of the subdivision streets showing boring locations,
b) logs containing the required data for all borings made,
c) particle size analysis and limits for all soil samples taken,
d) AASHTO classification for each soil sample as determined by AASHTO procedure M145, and,
e) a profile view of each street with borings plotted to scale showing the AASHTO classification of soils encountered.

The Department reserves the right to make check soil survey borings and inspect testing laboratories as part of our review of the developer's investigation work.

PARTICLE SIZE ANALYSIS OF SOILS

Corresponding Tests AASHTO T88
ASTM D422

1. SCOPE

1.1This method describes a procedure for the quantitative determination of the distribution of particle sizes in soil.

2. APPARATUS

2.1The apparatus shall consist of the following:

2.1.1Balance - a balance sensitive to 0.1 gram (0.004 oz) for weighing the material passing a (No. 10) 2.00 mm sieve; for larger samples, the balance should be sensitive to within 0.1 percent of the sample to be weighed.

2.1.2Stirring Apparatus - a mechanically operated stirring apparatus consisting of an electric motor suitably mounted to turn a vertical shaft at a speed not less than 10,000 revolutions per minute without load, a replaceable stirring paddle made of metal, plastic or hard rubber similar to one of the designs shown in Figure 1, and a dispersion up conforming to either of the designs shown in Figure 2.

2.1.3Sieves - A series of sieves of square mesh woven cloth, conforming to the requirements of AASHTO M92, (ASTM E11-70) WIRE CLOTH SIEVES FOR TESTING PURPOSES. The sieves normally required are as follows:

Standard Designation, mm		Alternate Designation	
75	4.75	3 in.	No. 4
50	2.00	2 in.	No. 10
25.0	0.425	1 in.	No. 40
9.5	0.075	3/8 in.	No. 200

2.1.4Beaker - A beaker of approximately 400-ml (0.01 Gal.) capacity.

2.1.5Container - A porcelain evaporating dish or other suitable container.

2.1.6Oven - A thermostatically controlled drying oven capable of maintaining temperatures of 110 degrees $\pm$ 5 degrees C (230 degrees $\pm$ 9 degrees F) for drying washed samples.

2.1.7 Sampler Splitter - A suitable riffle sampler or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines. The width of the container used to feed the riffle sample splitter should be equal to the total combined width of the riffle chutes.

3. REQUIREMENTS FOR WEIGHING

3.1 The weight of the representative portion of the original air-dry sample shall be determined to within 0.1 percent. (For example a 1000 gram (2.2 lb.) sample and the size fractions of the 1000 gram (2.2 lb.) sample retained on the No. 10 (2.00 mm) sieve shall be weighed to the nearest gram). The weight of the representative portion passing the No. 10 (2.00 mm) sieve shall be determined to within 0.1 gram. (For example a 100 gram (3.5 oz.) sample and the size fractions of the 100 gram (3.5 oz.) sample passing the No. 10 (2.00 mm) sieve shall be weighed to the nearest 0.1 gram).

4. SAMPLES

4.1 The test samples for particle size analysis shall be prepared in accordance with DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLES FOR TESTS. The representative portion of the original air-dry sample selected for test shall be weighed. The weight of this sample shall be approximately 1000 grams (2.2 lb.) or more.

4.2 The size of the representative portion passing the No. 10 (2.00 mm) sieve shall be approximately 110 grams (3.9 ox.) for sandy soil and approximately 60 grams (2.1 oz.) for silty or clayey soils.

4.3 The sample selected in Subsection 4.1 shall be separated on the No. 10 (2.00 mm) sieve as described in DRY PREPARATION OF DISTRUBED SOIL AND SOIL AGGREGATE SAMPLES FOR TESTS. One portion contains only particles retained on the No. 10 (2.00 mm) sieve while the other portion contains only particles passing the No. 10 (2.00 mm) sieve. The portion passing the No. 10 (2.00 mm)_ sieve shall be reduced by the use of a riffle sampler or sample splitter to a representative size fraction as noted in Subsection 4.2.

4.4 The remaining portion passing the No. 10 (2.00 mm) sieve shall be separated by means of a No. 40 (0.425 mm) sieve in accordance with DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLES FOR TESTS, Section 6.

5. SIEVE ANALYSIS OF FRACTION RETAINED ON NO. 10 (2.00 MM) SIEVE

5.1 The portion of the sample retained on the No. 10 (2.00 mm) sieve shall be separated into a series of sizes by the use of the 3 in., 2 in., 1 in., 3/8 in., and the No. 4 (75, 50, 25, 9.5 and 4.75 mm) sieves, and using other sieves as may be needed depending on the sample or upon the specification for the material beilng tested.

5.2 The sieving operation shall be conducted by means of a lateral and vertical motion of the sieve, accompanied by jarring action so as to keep the sample moving continuously over the surface of the sieve. In no case shall fragments in the sample be turned or manipulated through the sieve by hand. Sieving shall be continued until not more than 1 percent by weight of the residue passes any sieve during 1 minute. When sieving machines are used, their thoroughness of sieving shall be tested by comparison with hand methods of sieving as above described.

5.3 The portion of the sample retained on each sieve shall be weighed and the weight recorded although it shall be permissable to record the accumulated weights as the contents of each successive sieve is added to the fractions previously deposited on the scale pan. A check on the weight values may be secured by weighing the portion passing the No. 10 (2.00 mm) sieve and adding this value to the weight of the portion retained on the No. 10 (2.00 mm) sieve.

6. SIEVE ANALYSIS OF FRACTION PASSING THE nO. 10 (2.00 MM) SIEVE

6.1 The approximately 110- or 60- gram (3.9 or 2.1 oz.) sample shall be weighed, placed in a beaker of approximately 400 ml (0.1 gal) covered with clear water, stirred thoroughly with a glass rod and allowed to soak. The contents of the beaker shall then be washed into one of the dissersion cups shown in Figure 2, water added until the cup is more than half full, and the contents dispersed for a period of approximately 1 minute in the mechanical stirring apparatus.

6.2 The contents of the dispersion cup shall then be washed on a No. 200 (0.075 mm) sieve. The fraction retained on the No. 200 (0.075 mm) sieve shall be placed in a container, dried in an oven to constant weight at 230 degrees ± 9 degrees F (110 degrees ± degrees C) and a sieve analysis made using the required sieve sizes smaller than the No. 10 (2.00 mm).

Note 1: The term weight is temporarily used in this procedure because of established trade usage. The word may be used to mean both force and mass and care must be taken to determine which is meant in each case (SI unit for force = newton and for mass - kilogram).

Note 2: Example calculation are shown on an attached worksheet.

DETERMINING THE LIQUID LIMIT OF SOILS

Corresponding Tests AASHTO T89
ASTM D423

1. DEFINITION

1.1 The liquid limit of a soil is that water content as determined in accordance with the following procedure as which the soil passes from a plastic to a liquid state.

2. APPARATUS

2.1 The apparatus shall consist of the following:

2.1.1 Dish - A porcelain evaporting dish or similar mixing dish, about 4 1/2 in. (115 mm) in diameter.

2.1.2 Spatula - A spatula or pill knife having a blade about 3 in. (76 mm) in length and about 3/4 iln. (19 mm) in width.

2.1.3 Liquid Limit Device - A motor driven or manually operated mechanical device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Fig. 1. The motor driven device shall be calibrated to give the same liquid limit as obtained with the manually operated device.

2.1.4 Grooving Tool - A grooving tool conforming to the dimensions shown in Fig. 1.

2.1.5 Gage- A gage, whether attached to the grooving tool or separate, conforming to the critical dimension "e" shown in Fig. 1 and may be , if separate, a metal bar 10.00 $\pm$ 0.02 mm (0.394 $\pm$ 0.001 in) thick and approximately 50 mm (2 in) long.

2.1.6 Containers - Suitable containers such as metal cans with lids which will prevent loss of moisture during weighing.

2.1.7 Balance - A balance sensitive to 0.01 g.

2.1.8 Oven - A thermostatically controlled dying oven capable of maintaining temperatures of 100 degrees $\pm$ degrees C (230 degrees $\pm$ 9 degrees F) for dryiong moisture samples.

3. SAMPLE

3.1 A sample weighting about 100 g. (3.5 oz.) shall be taken from the thoroughly mixed portion of the material passing the 0.425 mm (No. 40) sieve which has been obtained in accordance with the procedure specified in DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLES FOR TESTS.

4. ADJUSTMENT OF DEVICE

4.1 The liquid limit device shall be inspected to determine that the device is in good working order; that the pin connecting the cup in not worn sufficiently to permit side play; that the screws connecting the cup to the hanger arm are tight; the points of contact on the cup and base are not excessively worn; and that a groove has not been worn in the cup through long usage. The grooving tool shall be inspected to determine that the critical dimensions are as shown in Fig. 1.

4.2 By means of the gage and the adjustment plate H. Fig. 1, the height to which the Cup C is lifted shall be adjusted so that the point on the cup which comes in contact with the base is 0.394 $\pm$ 0.00 in. (10.00 $\pm$ 0.02 mm) above the base. The adjustment plate H shall then be secured by tightening the screws, I. With the gate still in place, the adjustment shall be checked by revolving the crank rapidly several times. If the adjustment is correct a slight ringing should will be heard when the cam strikes the cam follower. If the cup is raised off the gate or no sound is heard, further adjustment shall be made.

5. PROCEDURE

5.1 The soil sample shall be placed in the mixing dish and thoroughly mixed with 15 to 20 cc of distilled or demineralized water by alternatively and repeatedly sitrring, kneading, and chopping with a spatula. Further additions of water shall be made in increments of 1 to 3 cc. Each increment of water shall be thoroughly mixed with the soil as previously described before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the liquid limit device should not be used for mixing soil and water.

Note 1: Some soils are slow to absorb water, therefore, it is possible to add the increments of water so fast that a false liquid limit is obtained. This can be avoided if more mixing and/or time is allowed.

5.2 When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficent quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall then be squeezed and spread into the position shown in Fig. 2 with as few strokes of the spatual as possible, care being taken to prevent the entrapment of air bubbles within the mass. With the spatula the soil shall be leveled and at the same time trimmed to a depth of 10 mm (0.4 in.) at the point of maximum thickness. The excess soil shall be returned to the mixing dish. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the center line of the cam follower so that a clean sharp groove of the proper dimensions will be formed. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke. shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

5.3 The cup containing the sample prepared as described in subsection 5.2 shall be lifted and dropped by turning the crank F at the rate of two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 1/2 inch (12.7 mm). The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank F is turned.

Note 2: Some soils tend to slide on the surface of the cup instead of flowing, if this occurs, more water should be added to the sample and remixed, then the soil-water mixture placed in the cup, a groove cut with the grooving tool and subsection 5.2 repeated. If the soil continued to slide on the cup at a lesser number of blows then 25, the test is not applicable and note should be made that the liquid limit could not be determined.

5.4 A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. The container and soil shall then be weighed promptly to the nearest 0.01 gram and the weight recorded. The soil in the container shall be over-dried to a constant weight at 110 degrees ± 5 degrees C (230 degrees ± 9 degrees F) and weighed to the neareset 0.01 gram. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.

5.5 The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall then be washed and dried in preparation for the next trail.

5.6 The foregoing operations shall be repeated for at least two additional protions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25 - 35, 20 - 30, 15 - 25, so the range in the three determinations is at least 10 shocks.

6. CALCULATIONS

6.1 The water content of the soil shall be expressed as the moisture content in percentage of the weight of the overdried soil and shall be calculated as follows:

$$\text{Percentage Moisture} = \frac{\text{wt. of water}}{\text{wt. of oven-dried soil}} \times 100$$

7. PREPARATION OF FLOW CURVE

7.1 A "Flow Curve" representing the relation between moisture content and corresponding number of shocks shall be plotted on a semi-logarithmic graph with the moisture contents as abscissae on the arithmetical scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three or more plotted points.

8. LIQUID LIMIT

8.1 The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

Method B (One Point Determination)

9. SAMPLE

9.1 A sample weighing about 50 grams (1.8 ox.) shall be taken as described in Section 3.

10. PROCEDURE

10.1 The procedure shall be the same as prescribed in Subsection 5.1 through 5.5 except the moisture sample taken in accordance with Subsection 5.4 shall be taken only for the accepted trail.

10.2 One groove closure shall be considered acceptable.

10.3 For accuracy equal to that obtained by the standard three point method, the accepted number of blows for groove closure shall be restricted between 22 and 28 blows.

11. CALCULATION

11.1 The water content of the soil at the time of the accepted closure shall be calculated in accordance with Section 6 and the result reported as the liquid limit.

11.2 Report liquid limit to nearest whole number.

DETERMINING THE PLASTIC LIMIT AND PLASTICITY INDEX OF SOILS

Corresponding Tests AASHTO T90
ASTM D424

1. DEFINITIONS

1.1 The plastic limit of a soil is the lowest water content determined in accordance with the following procedure at which the soil remains plastic. The plasticity index of a soil is the range in water content, expressed as a percentage of the weight of the ovendried soil, within which the material is in a plastic state. It is the numberical difference between the liquid limit and plastic limit of the soil.

2. APPARATUS

2.1 The apparatus shall consist of the following:

2.1.1 Dish - A porcelain evaporating dish, or similar mixing dish about 4 1/2 inches (115 mm) in diameter.

2.1.2 Spatula - A spatula or pill knife having a blade about 3 inches (76 mm) in length and about 3/4 inch (19 mm) in width.

2.1.3 Surface for Rolling - A ground glass plate or piece of smooth, unglazed paper on which to roll the sample.

2.1.4 Containers - Suitable containers, such as metal cans with lids which will prevent loss of moisture during weighing.

2.1.5 Balance - A balance sensitive to 0.01 g.

2.1.6 Oven - A thermostatically controlled drying oven capable of maintianing temperatures of 110 degrees